Astrophysics Roadmap Science Challenge: Polarimetry of Spatially Unresolved Exoplanets

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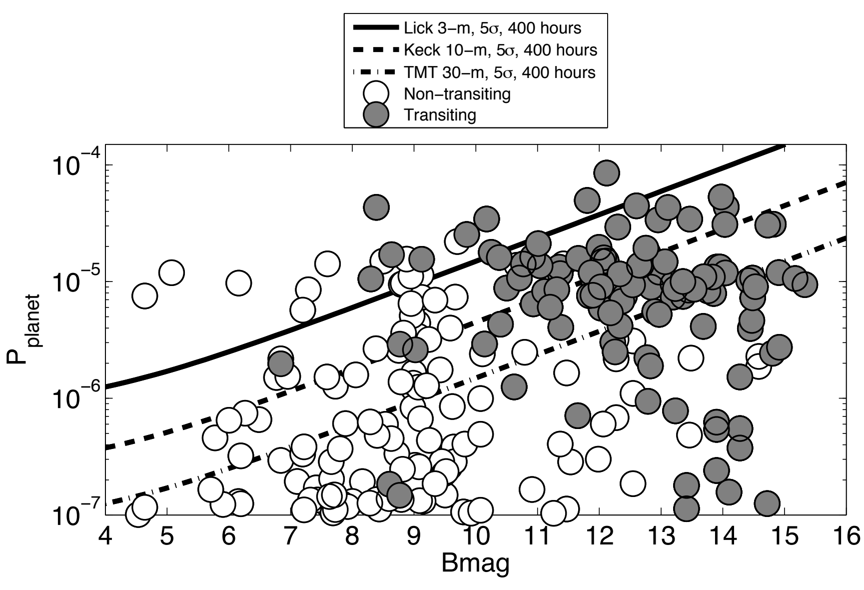
The detection of scattered light from exoplanets gives direct access to the structure and composition of their atmospheres. Most scattered light experiments target nearly edge-on, transiting systems. The temporal changes that occur during planetary occultations are used to suppress systematic errors that would otherwise overwhelm the planetary signal. Linear polarimetry allows direct detection of scattered light from exoplanets, because the polarization state of light scattered by a planetary atmosphere distinguishes it from both the direct light from the host star and the Wien tail of thermal re-radiation from the planet. Scattered flux is identifiable regardless of orbital inclination, because both degree and position angle of polarization are modulated continuously throughout the orbit. Orbital inclination, mean number of scattering events, and scattering particle size and index of refraction are discernable with polarimetry. Multiband polarimetry allows composition of the scattering particles to be determined. Indeed, the discovery of spherical droplets of sulfuric acid suspended in the Venusian atmosphere was made by ground-based polarimetry 40 years ago, and technology has matured to the point where such discoveries are now possible for exoplanets. Comparison of atmospheric properties for the following classes of spatially unresolved exoplanets is scientifically exciting:

- Canonical hot Jupiters: expected to be dark from highly refractory cloud particles and significant alkali absorption. Detection timescale: 1 year (single band, 3-m telescope), 8 years (multiband, 10-m telescope).
- Close-in Jovians with large or non-spherical scattering surfaces: these exoplanets experience gaseous escape due to extreme stellar insolation or tidal deformation due to extreme proximity to their host star. Such scattering surfaces should impart significant polarization. Detection timescale: 2 years (single band, 3-m telescope), 8 years (multiband, 10-m telescope).
- Jovians on highly eccentric orbits: these exoplanets spend most of their time in colder regions, so dark, refractory cloud particles may not be present. Their close periastron distances and high albedo, Rayleigh-scattering atmospheres should provide significant polarization. Detection timescale: 3 years (single band, 3-m telescope), 10 years (multiband, 10-m telescope).
- Close-in, hot super-Earth/sub-Neptune exoplanets: these exoplanets may not possess refractory cloud particles or significant alkali absorbers. High albedo, Rayleigh-scattering atmospheres should provide significant polarization and partially compensate for their small radii. Detection timescale: 12 years (multiband, 10-m telescope).



The figure at left shows actual sensitivity limits for the POLISH2 high precision polarimeter at the Lick 3-m and scaled to various telescopes. Expected exoplanetary polarization is estimated by a 0.1 albedo for hot Jupiters and higher albedos for exoplanets with larger semimajor axes. In 20 years, 30-m telescopes will detect scattered light from Jovians at 1 AU. In 30 years, spectropolarimetry on 30-m telescopes may have the sensitivity to observe the "red edge" due to vegetation on the largest exoplanets in the habitable zones of their stars.